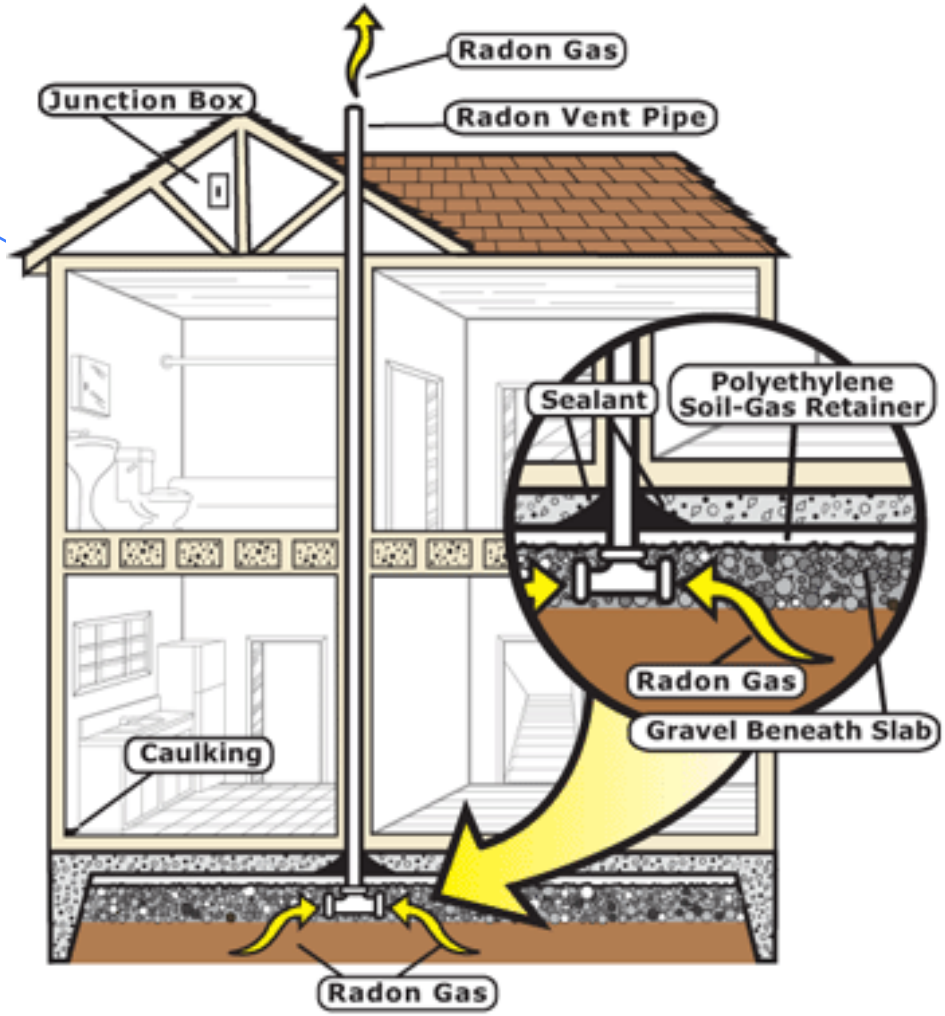
Building Radon Out – Get it Right, Save Costs and Reduce Your Liability



HPBZ Radon Presentation at IBS 2016 – Booth S2436

January 21 – 10:30

HPBZ Radon Session Team Presenters

- **Bruce Snead, Kansas State University, Manhattan, KS**
- **Matt Koch, Southern Radon Reduction, Atlanta, GA**
- **Arnold Drennen, Drennen Custom Contracting, Fort Collins, CO – Member, NAHB Board**
- **Chad Robinson, Building Performance Company, Salina, KS – VP, Kansas Building Industry Association**
- **with thanks to many industry contributors!**

Session Objectives

- **Why You Should Build Radon Resistant**
- **What Cost Effective Techniques and Options Achieve in Time, Money and Risk Reduction**
- **What Options Will Work Best for My Homes**

Agenda

- Radon Facts for Builders
- RRNC Applications
- Codes and Standards for RRNC
- RRNC Evaluation Results
- Costs and Cost Savings
- Liability Concerns
- Performance Issues
- Builder and mitigator examples/case studies
- Q and A

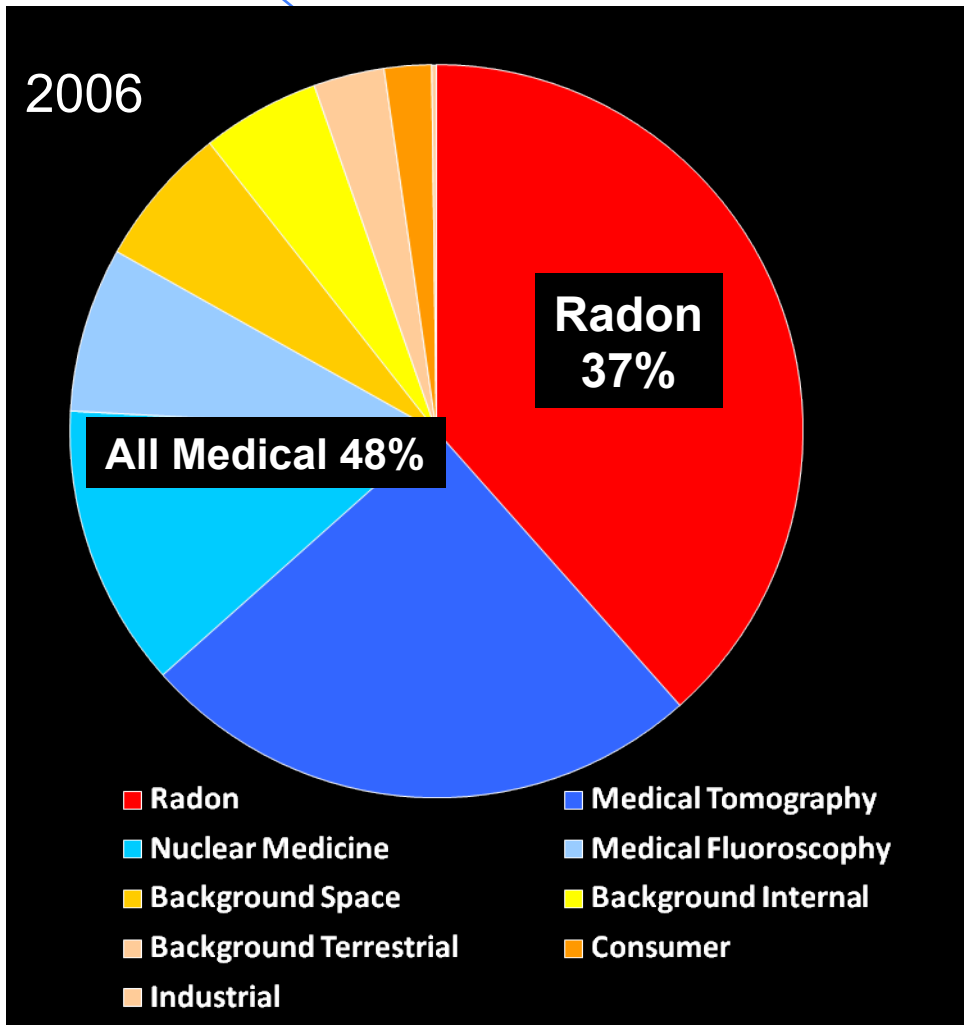
"Radon is a Serious National Health Problem"

- American Lung Association
- American Medical Association
- Environmental Protection Agency
- National Academy of Sciences
- National Council on Radiation Protection and Measurement
- U.S. Surgeon General
- World Health Organization

Radon Exposure in Homes Is Significant

- **Radon 222 - Naturally Occurring Radioactive Gas Element**
  - **Not Detected by Human Senses**
  - **Indoor concentrations are created by the way we design, build, and operate buildings where we live, learn, and work**

Average annual radiation source exposures for US citizens



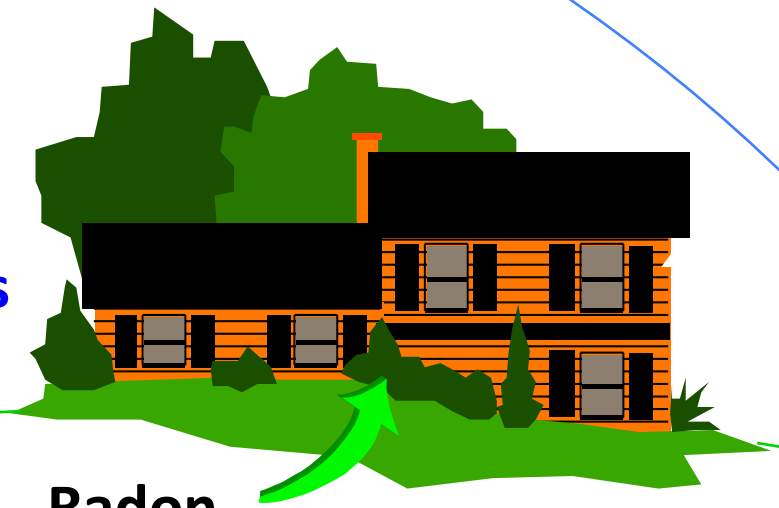
Basic Facts

- Radon is Everywhere!
- The only way to know the radon level is to test – it can't be predicted
- Your house may be low, your neighbor's may be high
- 95-99 out of 100 high homes can be fixed with fan powered soil suction systems

Radon Entry and Common Concentrations

EPA Action Level
4.0 pCi/L
The EPA's action level of 4.0 pCi/L is not a health based number

The EPA recommends mitigation at levels between 2.0 pCi/L and 3.9 pCi/L



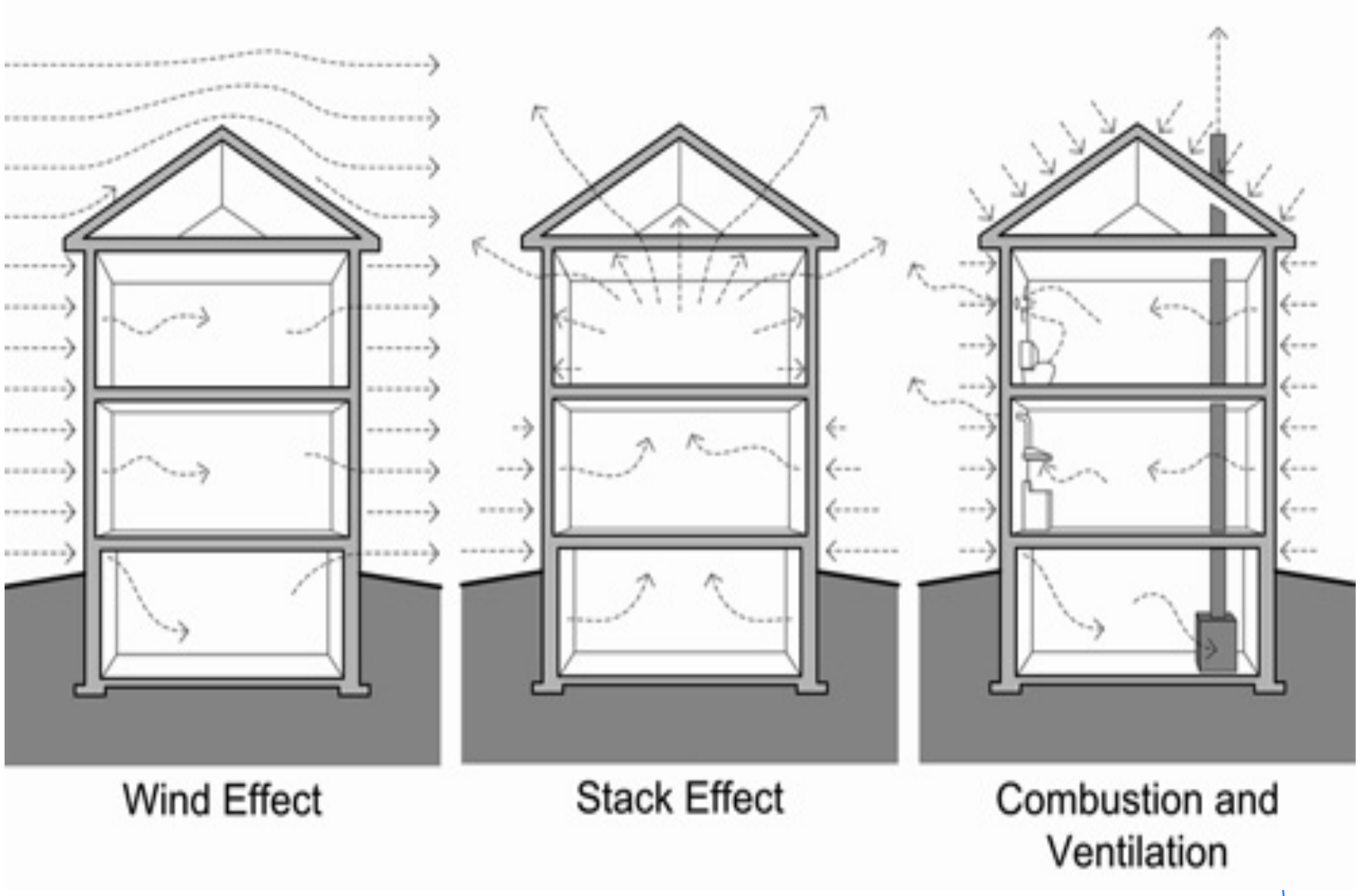
0.4 pCi/L *-U.S. annual average outdoors –

1.3 pCi/L *-U.S. annual average indoors in homes (living areas) –

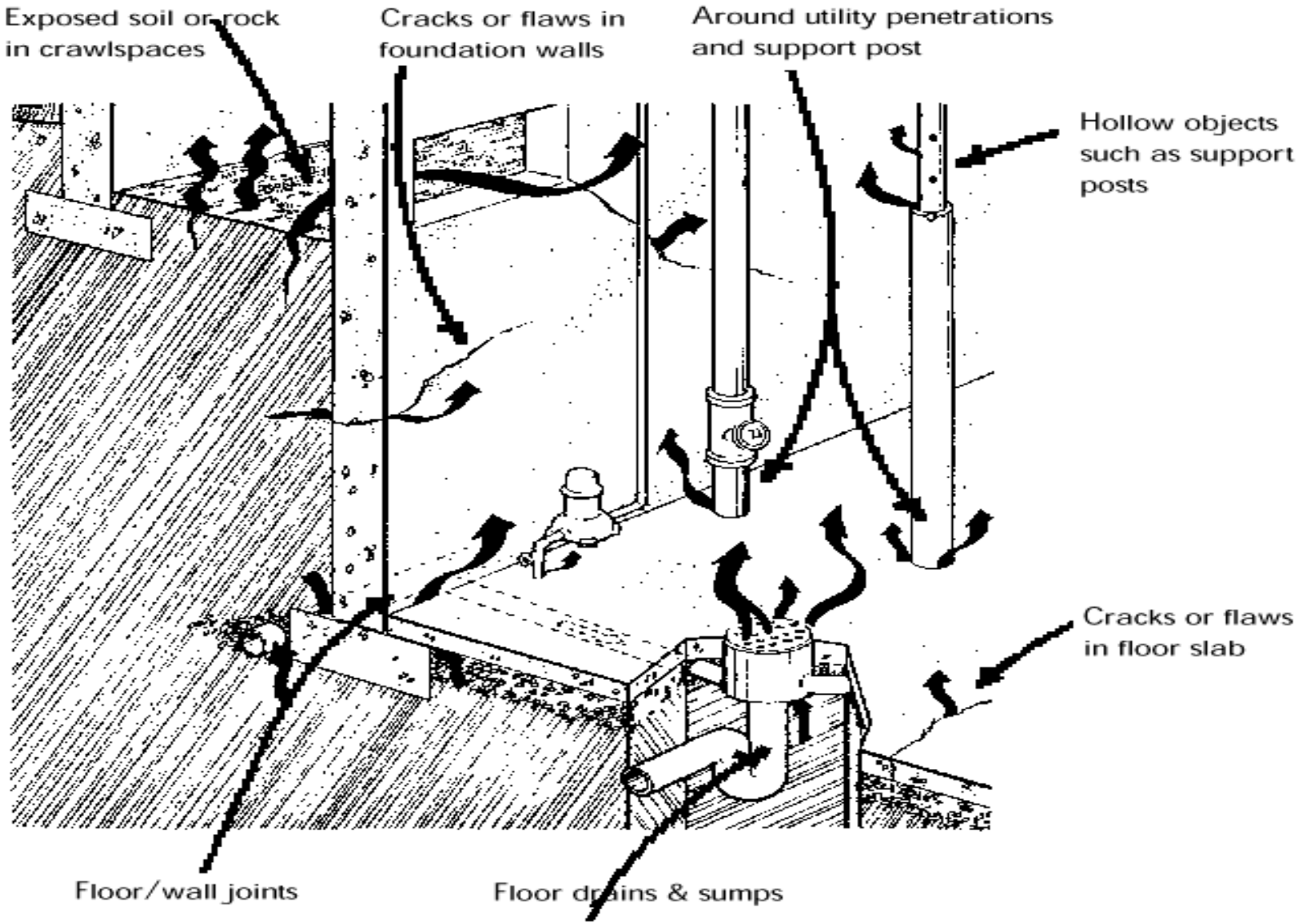
The Concentration of Radon in a Building Depends Upon:

- Source of radon and its strength
- Air pressure differences
- Air pathways in soil and through foundation
- Air changes per hour – ventilation rate

Air Pressure Variables



How Radon Enters Your Home

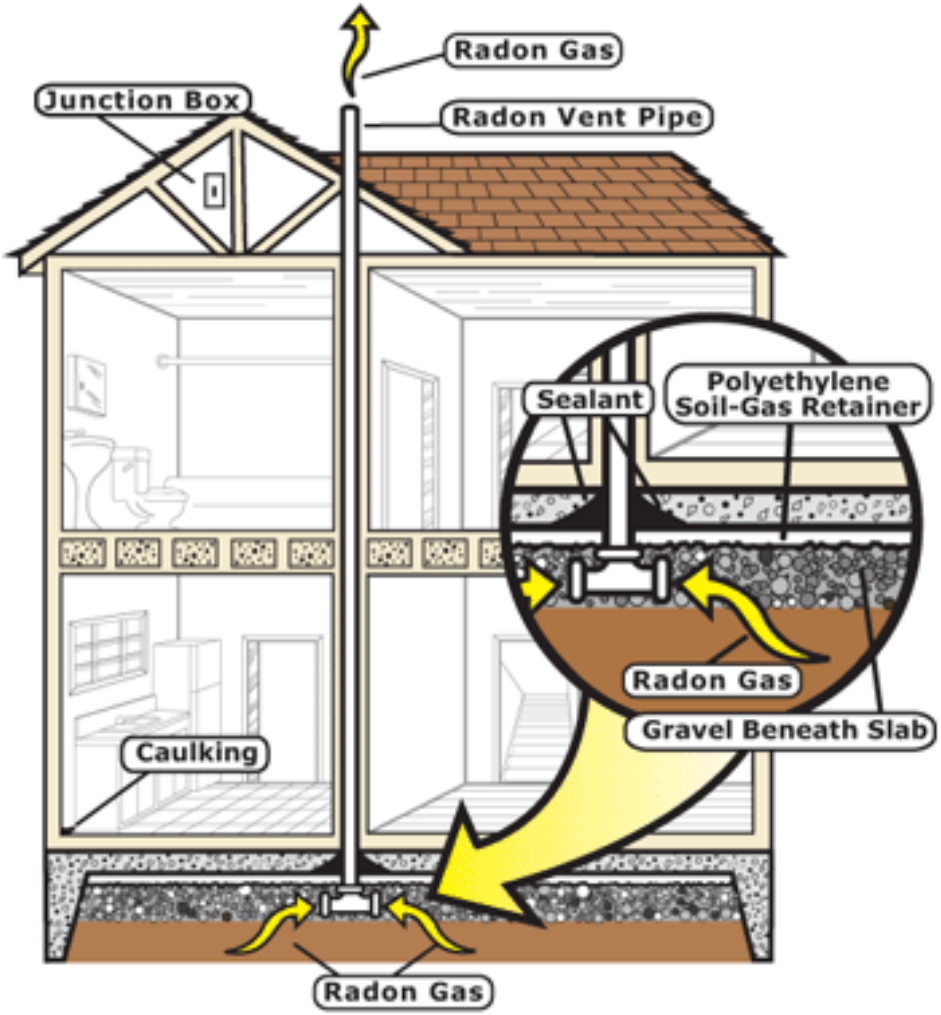


Effect of Ventilation Rates on Indoor Radon Concentrations

- Just because a house is leaky or tight does not mean it will have low or high radon levels
  - In part, the indoor radon concentrations depend upon:
  - the percentage of air infiltrating that is soil gas (which can range from 1-20% of total infiltration)
  - the radon source strength in that soil gas, and
  - the overall air change rate of the structure
- Making homes tighter can increase the radon concentration due to decreased dilution from outdoor air

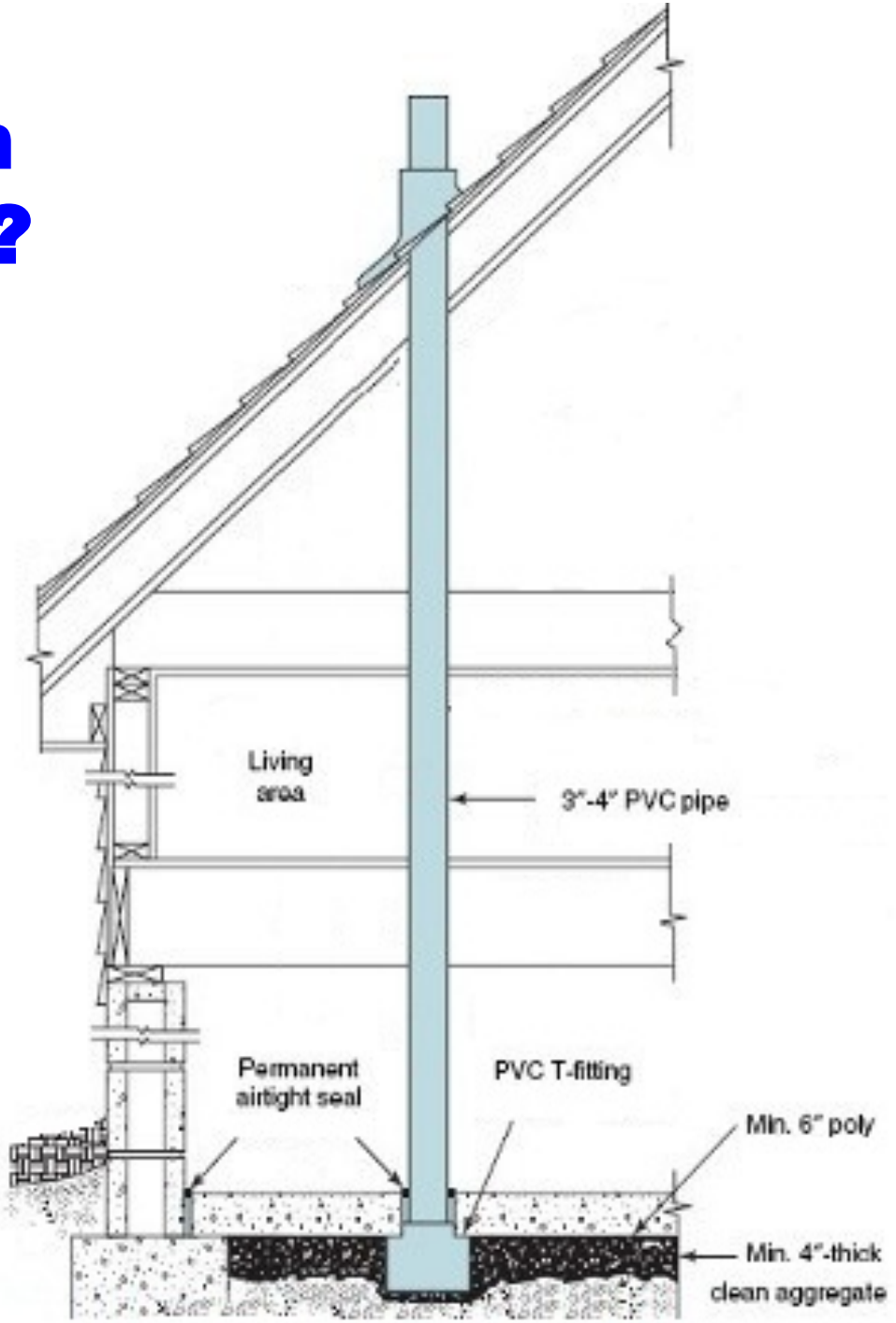
What Does It Take to Build the House Radon Resistant?

- Foundation gas collection system
- Pipe to convey gas through roof
- Provision to add fan if needed



How Is the System Supposed to Work?

- It is designed to vent radon from beneath the structure by use of a vent pipe routed through the conditioned space of a building, connecting the sub-slab area with outdoor air.
- The warmed air in the pipe rises, creating a slight vacuum (pressure differential) on the cooler soil gas.
- Known as Passive Soil Depressurization - PSD

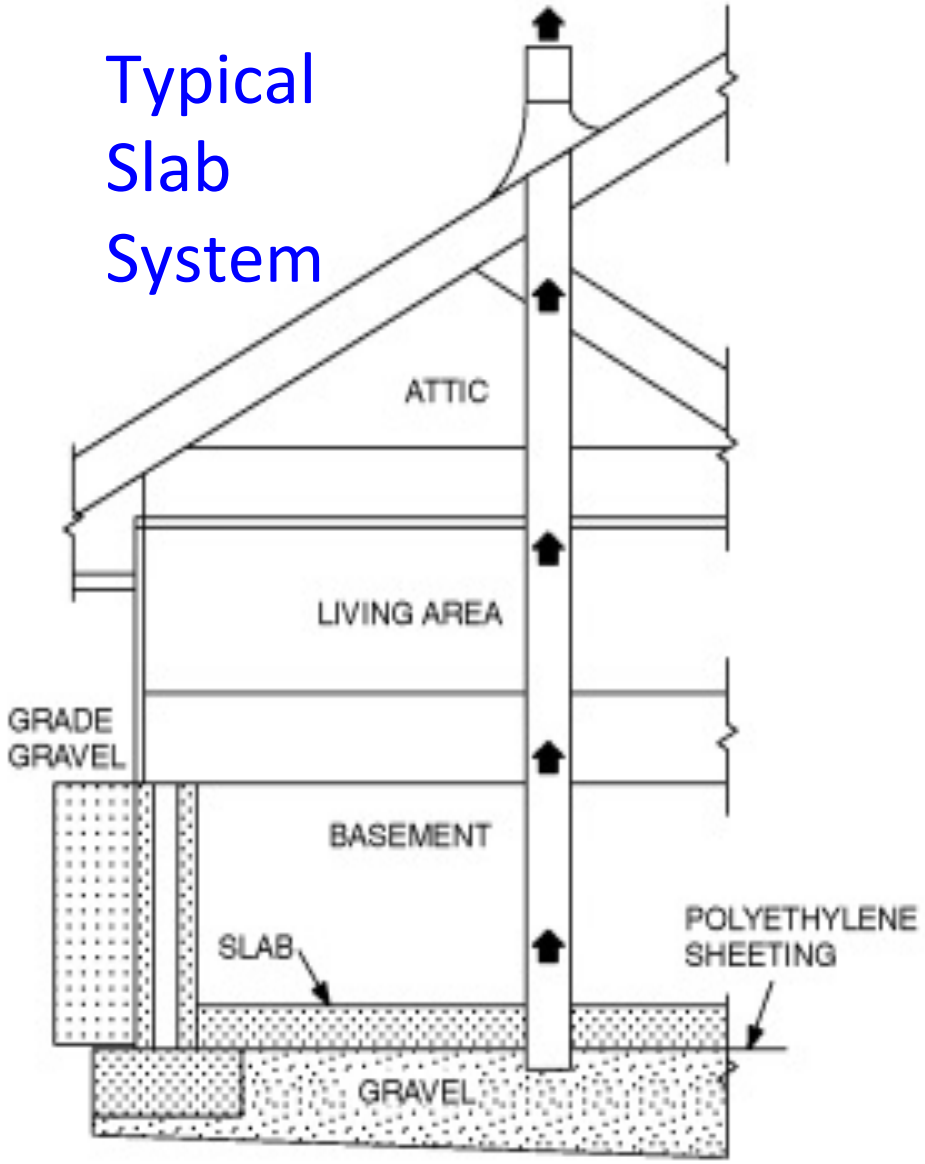


Two Major Reasons Passive Soil Depressurization is Used

1. To reduce indoor radon concentrations
   - In general, about 50% reduction is expected if properly installed
2. To make the house easy to fix if further radon reduction is needed
   - By activation with a fan
     - Stack must easily accessible outside conditioned space for fan installation
     - Power must be available near fan
     - Major openings between soil and occupied space must be sealed

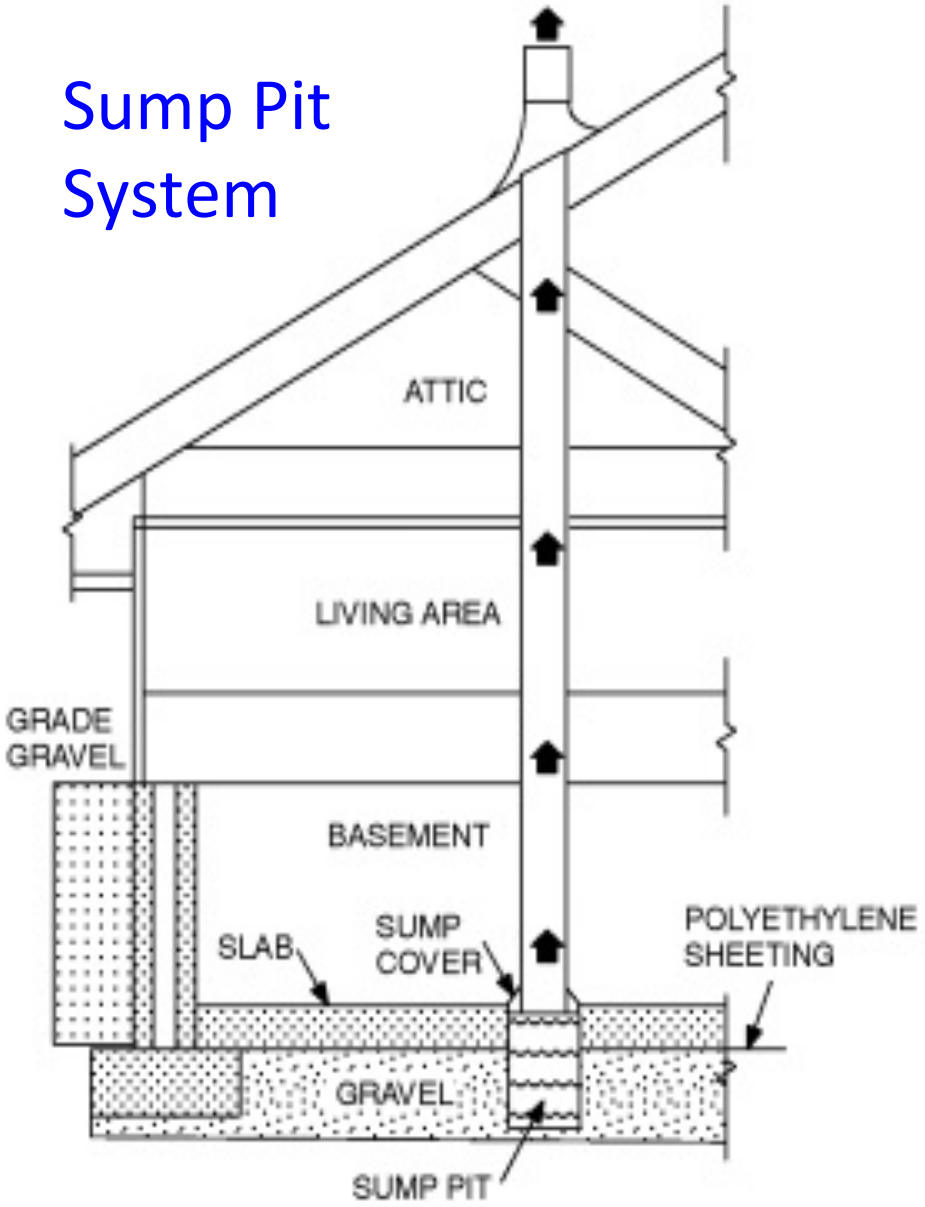
TYPICAL SUBSLAB DEPRESSURIZATION
PASSIVE RADON SYSTEM

Typical Slab System

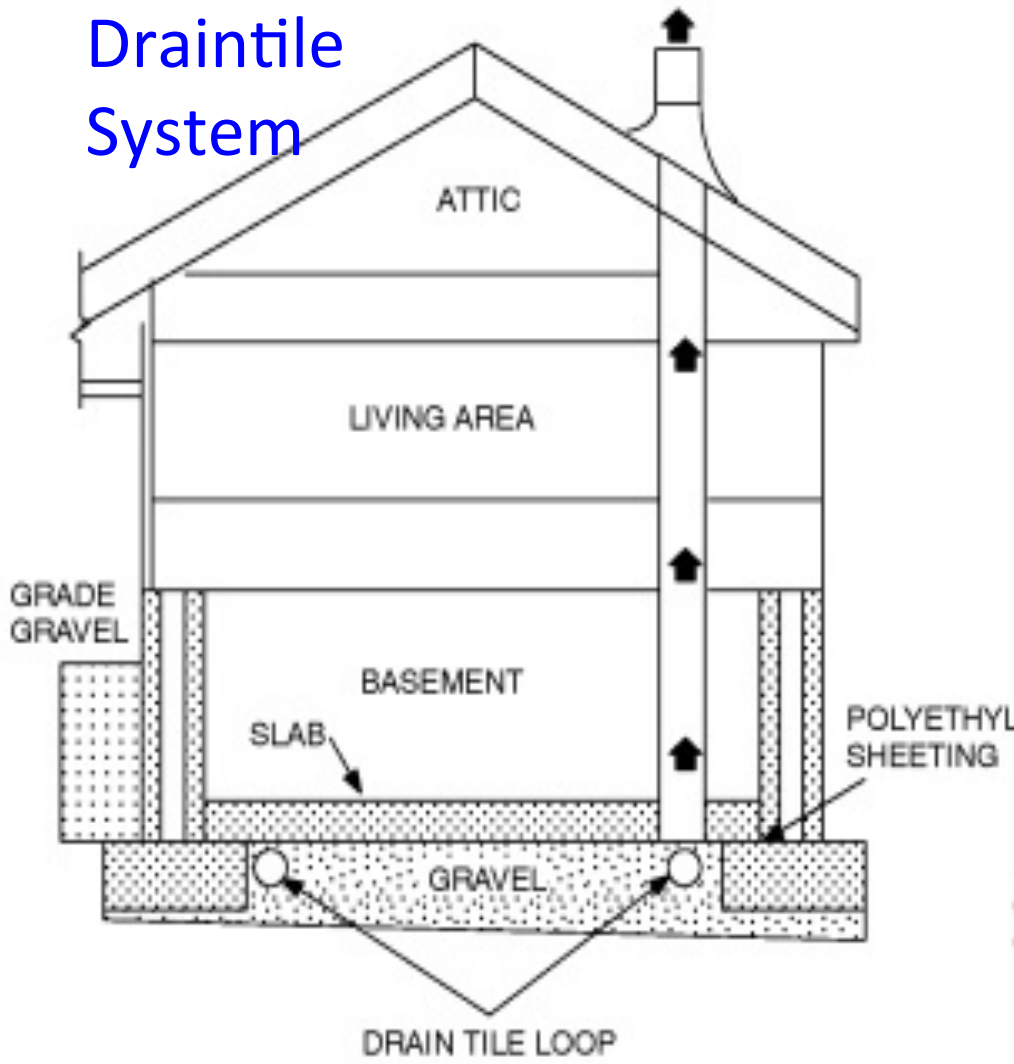


PASSIVE RADON SYSTEM VENTED
THROUGH SUMP

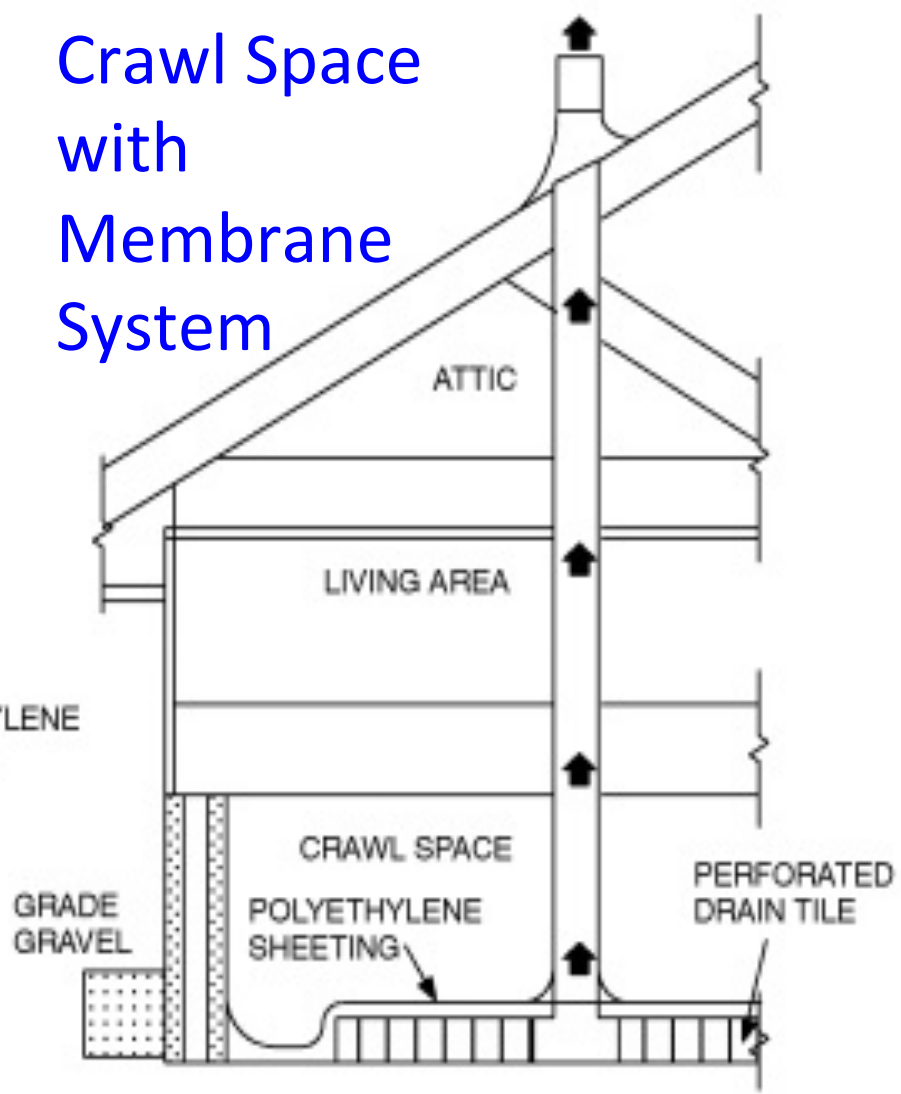
Sump Pit System



Draintile System



Crawl Space with Membrane System



Resource Handout for You

Building In Radon Control

Radon is a tasteless, colorless and odorless gas

occuring naturally in soil and rock. Radon is a leading cause of lung cancer, second only to cigarette smoking.

Installing a radon system during construction of a structure doesn't cost a lot, and enhances the value of the property.

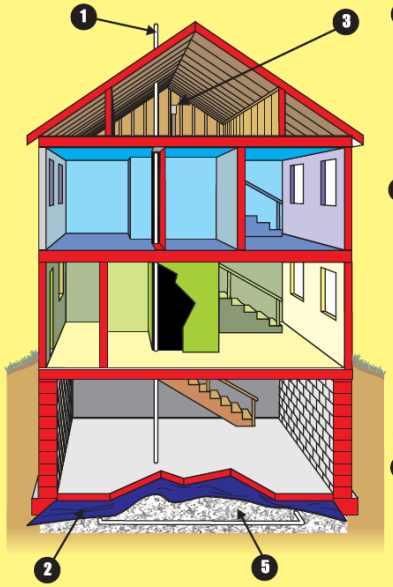
How a radon system works.

Crushed stone under the house provides an easy pathway for the radon to migrate towards the vent piping, where it is drawn upwards and released safely into the atmosphere.

The mitigation system will lower radon levels even without a fan, but it may not be enough. A fan may be required. A simple radon test will provide the answer.

1 PVC Pipe carries radon from under the slab to above the roof.
A straight run of piping reduces friction losses. Piping MUST NOT be in an exterior wall; interior locations allow the thermal conduction of heat to cause air in the pipe to rise. Attic section needs space for the fan if required. Proper venting requires the pipe to extend above the roof. Four inch PVC pipe is best for system quietness and efficiency.

2 Plastic Sheeting is placed on top of the crushed stone. The plastic is part of an air barrier between the basement and the subslab, and also is a moisture blocking layer.
Ensure plastic is not punctured during pouring or working of concrete.



Important. *After the home is occupied, only home owners or state certified radon contractors may install fans or work on the radon system.*

3 Electrical Junction Box in case a radon fan is needed later.
NEC requires a plugged fan to be within 6 feet of an outlet. Vent pipe and junction box placement need to account for this.

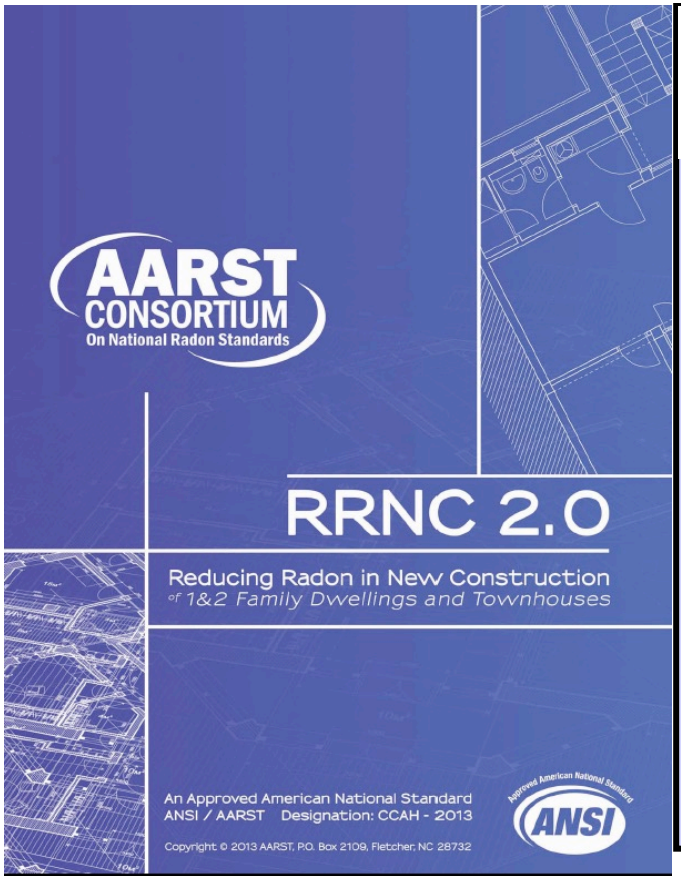
4 Seal and Caulk all openings in the concrete floor.
As part of an air barrier between the subslab and the basement, seal the floor-wall joints and control joints with urethane caulking, and the sump lids with silicon caulking. If a fan needs to be installed after testing, this barrier will prevent basement air from being drawn drawn under the subslab.

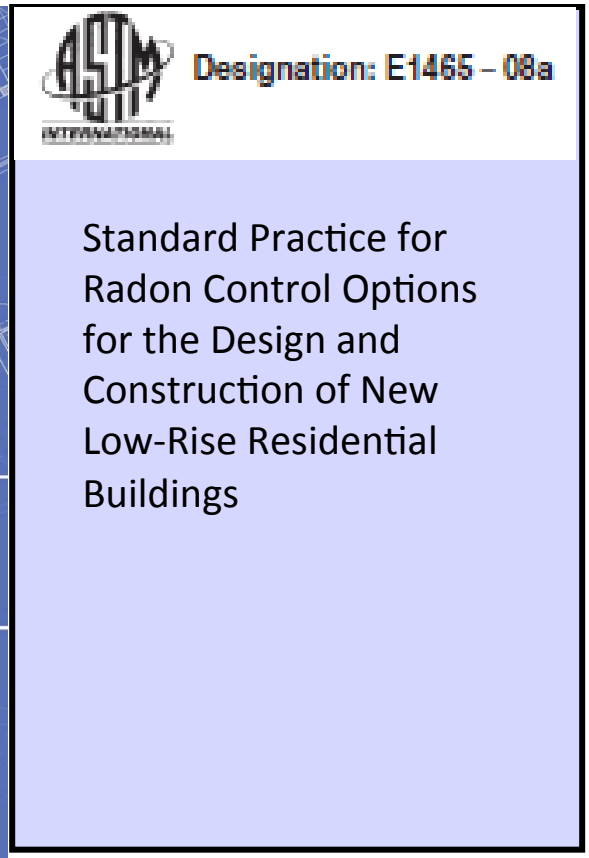
5 Crushed Stone under the slab allows radon to move freely underneath the house.
Four to six inches of washed and clean 2B stone is best.

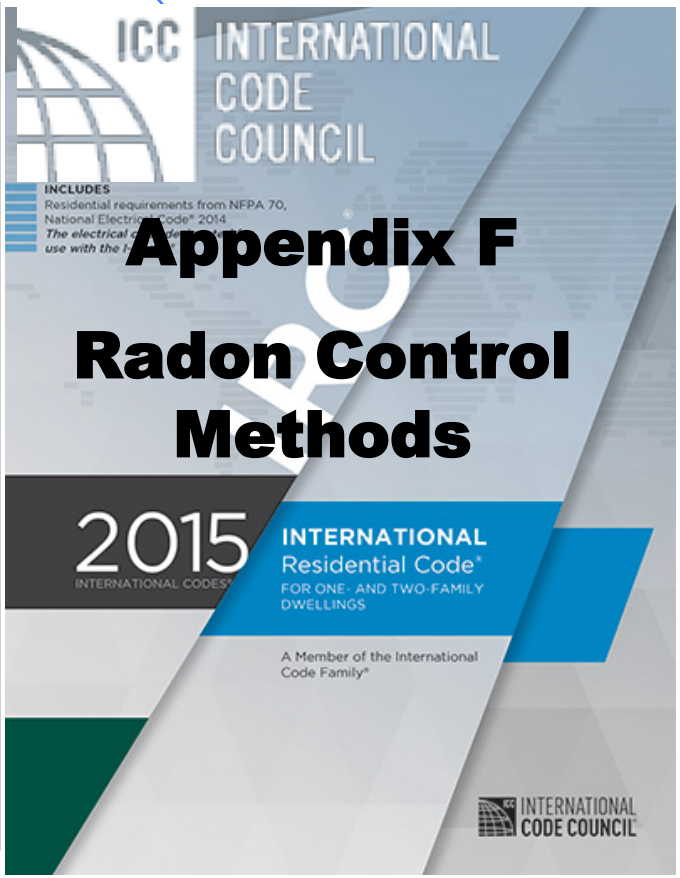
A radon test should be preformed immediately after the house is occupied, and a fan installed if results are greater than 4 pC/L.

For further information: IRC 2006 Appendix F, or
Pa. Dept. of Environmental Protection, Radon Division, or
www.state.pa.us PA Keyword:radon or 1-800-23RADON

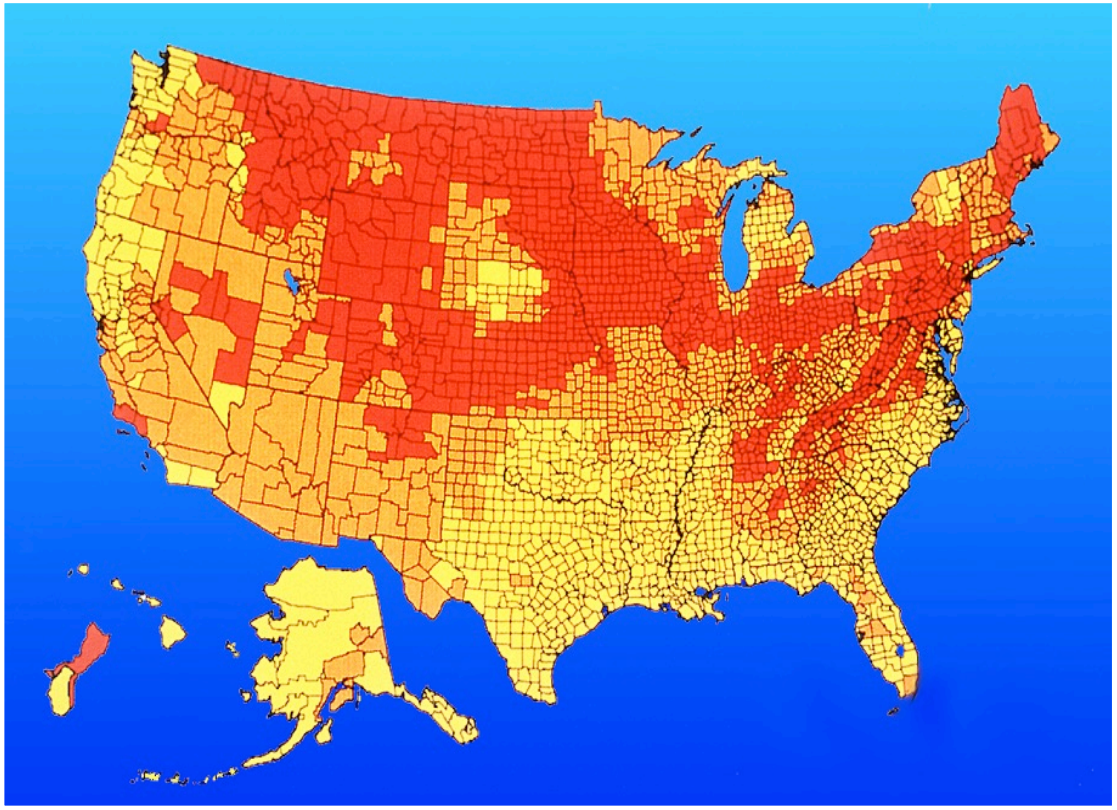
What Are the Codes and Standards to Be Followed? There are three:







International Residential Code (IRC) Appendix F: Intended for Zone 1



- Also may be adopted in other zones
- EPA Zones
  - Red = Zone 1 > 4.0
  - Orange = Zone 2, 2.0 to 4.0
  - Yellow = Zone 3 < 2.0

Jurisdictions with Radon Control Building Code Requirements

- States (statewide-maybe in zone 1 only)
  - Illinois
  - Maryland
  - Michigan
  - New Jersey
  - Washington
  - Oregon
  - Minnesota
- States (statewide but need local adoption)
  - Florida
  - Maine
  - Rhode Island
  - Virginia
- States (where local jurisdictions have adopted)
  - Alabama
  - Colorado
  - Georgia
  - Idaho
  - Iowa
  - Kansas
  - Montana
  - Maryland
  - Nebraska
  - New Mexico
  - New York
  - Ohio
  - Oklahoma
  - Pennsylvania
  - South Carolina
  - Tennessee
  - West Virginia
  - Wisconsin
  - Wyoming

IRC Appendix F: Section 103 Requirements (Overview)

1. General
2. Subfloor Preparation
3. Soil-Gas Retarder
4. Entry Routes
5. Passive Submembrane Depressurization (PSD) Systems: Crawlspace
6. PSD Systems: Basements and Crawlspace
7. Vent Pipe Drainage
8. Vent Pipe Access
9. Vent Pipe Identification
10. Combination Foundations
11. Building Depressurization
12. Power Source

Overview of Appendix F and ASTM E 1465

Length	**4 Pages**	**38 Pages**
Code Language	**Yes**	**No**
Ease of Use	**Straightforward but missing critical details**	**Complex and challenging**
Geographic	**EPA Zone 1**	**EPA Zones 1 and 2**
Type of System	**PSD**	**PSD or ASD**
Rn Testing Required?	**No**	**Yes**
Code Adoption History	**Extensive**	**Very Limited**

RRNC 2.0

- **Prescriptive Building Code with performance requirements**
- **Treat all foundation types (Rough In)**
  - **Soil Gas Collection Plenums**
  - **Piping**
  - **Electrical Junction Box**
- **True Radon Risk Reduction**
  - **Testing Required for Occupancy Permit**
  - **Activate System Rough In if Necessary**

RRNC 2.0 -Purposes

1. To specify radon control methods and techniques for use in dwelling units to reduce indoor radon concentrations to below the National Action Level (NAL) of 4 pCi/L
2. To provide minimum requirements for Rough-In of a Mitigation System and Activation of the Mitigation System, if required, in newly constructed dwelling units.
3. To provide a model set of requirements for adoption by states and local jurisdictions.
4. To provide a means for authorized personnel to inspect and evaluate a Mitigation System in new construction.

Summary of PSD Effectiveness Testing

Study	# Homes	Average Rn Capped	Average Rn Uncapped	Average % Rn Reduced	Comments
NAHB 1994	45	5.9	2.5	**57%**	Most built ~ EPA standards, some no poly, some no sealing; inspected during construction
East Moline, IL 1998	21	9.2	3.7	**59%**	Built ~ EPA standards but un-finished basements w/o poly; inspected during construction
Monroe Co., NY 2002	20	2.9	2.5	**12%**	Vent stacks NOT through conditioned space, no poly under slab
Muscatine, IA 2002	13	9.3	7.5	**20%**	12 homes had sub-slab sand NOT permeable layer, 1 home with sub-slab gravel had 51% radon reduction
Dane Co., WI 2003	7	11.1	4.7	**42%**	Built ~ EPA standards and inspected during construction; 1 house at 12 pCi/L with PSD had large leaks
Manhattan, KS 2002-2005	19			**31 - 37%**	Unsealed sump pits, vent stack NOT through conditioned space (1)

NAHB Research Center 1994 Radon Control in New Homes Study Results

- Radon average in 45 homes with various passive radon-resistant techniques ~ EPA
  - Capped (i.e., passive system blocked) = 5.9pCi/L
  - Uncapped (i.e., passive system working) = 2.5 pCi/L
- Some homes had no poly under slab and some did not have floor penetrations sealed

NAHB Research Center 1994 Radon Control in New Homes Study Results

- Short-term measurements in 20 of 45 homes were
  - Greater than 4pCi/L – with capped passive vent
  - Average capped = 10.7 pCi/L
  - Average uncapped = 3.7 pCi/L
  - 19 of 20 homes had reduced levels due to passive radon system

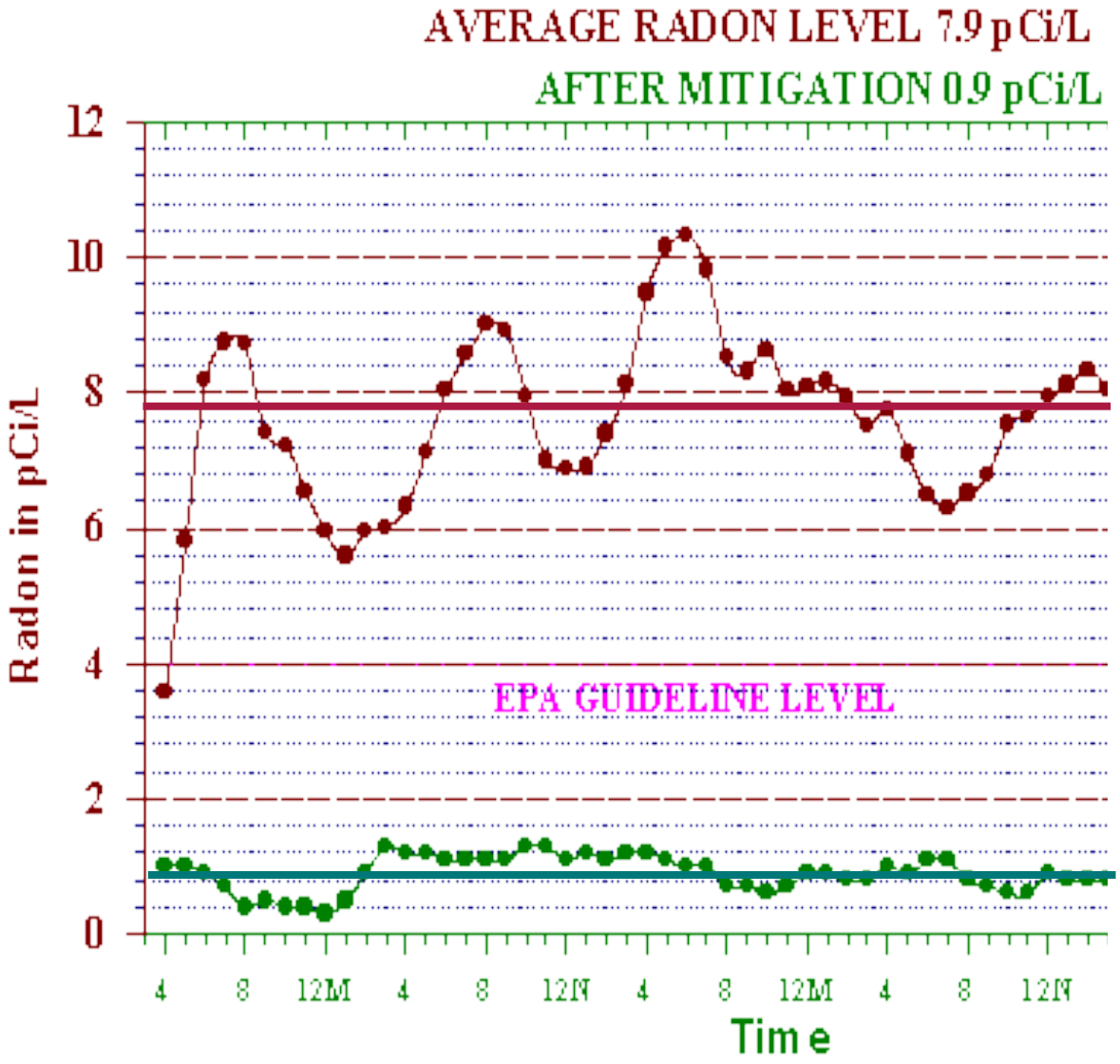
NAHB Research Center 1994 Radon Control in New Homes Study Results

- Short-term measurements in 25 of 45 homes were
  - Less than 4pCi/L – with capped passive vent
  - Average capped = 2.1 pCi/L
  - Average uncapped = 1.6 pCi/L
  - 17 of 25 homes had reduced radon levels due to radon passive venting

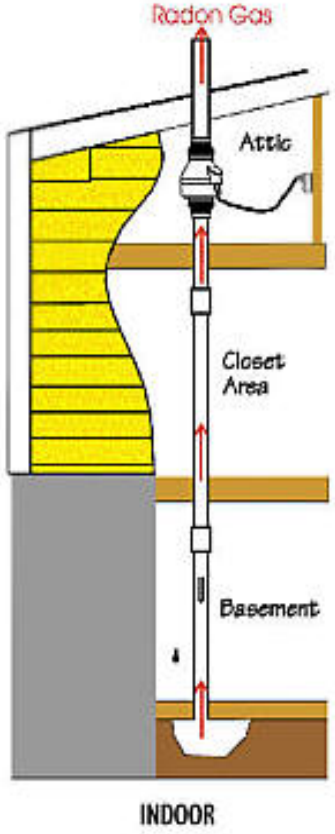
PSD Can Work But … It Needs To Be Done Correctly

- If not done correctly . . .
  - May not provide much, if any, radon reduction
  - Can make future activation, if needed, difficult, impractical, or impossible
- It is *highly important* to test all new homes for radon, even those with PSD
  - PSD does not guarantee < 4 pCi/l but . . .
    - It does reduce indoor radon and it provides a system ready for activation if needed

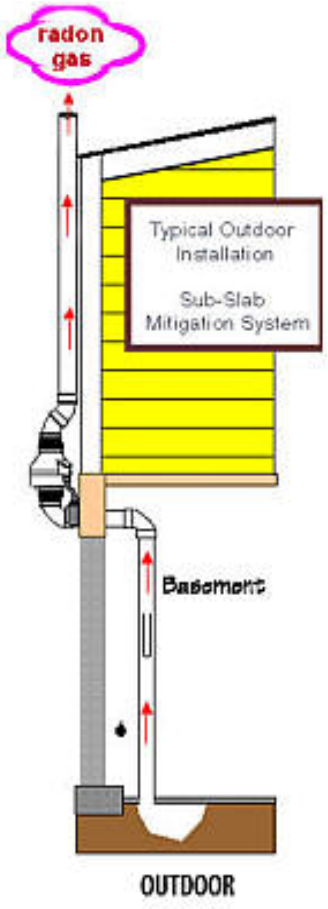
Radon Levels Before and After Active Mitigation



Indoor Fan



Outdoor Fan



Testing Reveals Performance!

- Installing RRNC properly enhances the potential that radon levels will be low.
- The only way to know if the system is successful is to test.
- Testing can occur when ready for occupancy.
- If the house tests above 4 pCi/L the system should be activated with a fan and system pressure indicator added to the pipe.

Liability Concerns

- This is a life safety system
- Buyer commonly assumes performance is assured just by presence of a system
- Untrained contractors doing work – no one to assume liability
- Lawsuits against builders for incorrectly installed systems

Costs and Cost Saving

- No RRNC can lead to systems being installed on the exterior
- Poor installation means redoing the work
- Poor installation means poor performance leading to more activations
- Electrical costs are less when run during construction
- Poor performance means more testing to clear the property
- Failed tests can delay closing on the property

Performance Issues

- Pipes Blocked by Construction Debris
- Pipes Blocked by Soil
- Stack Pipe too Small
- Pipe Routed Through Unheated Space
- Pipe does not Discharge Above Roof

Performance Issues

- Pipe Joints Note Sealed
- Pipe installed at 45 degree angle in attic. No room for fan
- Pipe installed directly next to truss member not allowing space for fan
- System Labels Lacking
- Radon Performance Tests not Done

Performance Issues

- Pipe inaccessible.
- Pipe in attic installed without slope across top of ceiling joists. Water collects in pipe.
- Pipe visible in basement but not in attic.
- Pipe not labeled in attic or basement. Only able to identify pipe due to lack of cleanout.

Performance Issues

- Subslab Permeable Layer Missing or Incomplete
- Sealing Incomplete
- Sumps Unsealed
- Isolated Subslab or Submembrane Areas
- Air Leaks from sub slab to the Outdoors

Sump Not Sealed
Poor Materials

Vent Stack Blocked by Concrete or Debris


Do You See Any Problem? Exterior Wall Pipe Run = Fail!

Pipe Run Through Interior Walls and Adjacent to Flue Chase is Optimum

Labels are critical – entire bathrooms have been discharged into radon vent pipes!

Pipe is resting on soil blocking air flow and membrane is not sealed around pipe

Vent pipe terminates near window and has a rain cap – requires relocation

Pipe location limits fan installation

This system - the builder forgot to put it in so the plumber did it after the fact. The pipe ran down into the slab and the end was encased in concrete. The pipe exited the side of the building and stopped right there

The passive vent-pipe is the one on the far right. Someone also used it as the vent for the sink drain! Let's put a fan on that and see what happens if sewer gas pulled through the fan.

The pipe comes out of the sealed sump pit, runs across the basement ceiling, and discharges at the exterior where you see the downturned PVC. This won't work!

Mitigator Comments About Activating Builder Installed PSD

- 36% required MAJOR repairs which I define as having to cut concrete, cut and "unstop" piping, or install new vacuum points.
- Also if the attic pipe is inaccessible or must be rerouted to the extent that it requires a new hole thru the roof.

Mitigator Comments About Activating Builder Installed PSD

- My experience has been that about 25% of activations of builder installed systems work fine, and 75% must be altered or abandoned.
- The most common fixes needed are cleaning out the suction pit, correcting the pitch of the piping, filling holes under tubs and sealing wall/floor joints, altering piping to allow room for a fan, completing roof penetrations, and installing electrical service.

Mitigator Comments About Activating Builder Installed PSD

- My statistics for the last 3 years show 40% of the activated builder pipes failed to reduce below 4.0 pCi/l when a fan was added.

Mitigator Comments About Activating Builder Installed PSD

- I have never activated a passive system that was installed by a builder that worked properly. The sad truth is they are usually installed by the least experienced and lowest paid person on the job site.

Mitigator Comments About Activating Builder Installed PSD

- Well, many variations have cropped up over the past 3 years- the builders, that actually took the time, to ask a certified mitigator for design help- have faired well- while others- not so much.
- Of all the passive stacks, I've come across (28) I've cut every one out.

Richmond American Homes
Radon Program Description

- Homes constructed in areas with High Radon Potential to receive Active radon control systems
  - EPA Zone 1 or State determined Zone 1 (whichever is higher)
- Homes constructed in areas with Moderate or Low Radon Potential offered fixed reimbursement to offset cost of mitigation if tested and mitigated in a timely fashion
- Initiated in 2010 and continues
- 7,513 new homes with active radon control systems installed in CO, PA, MD, VA and UT to date
- Design and practices based on ASTM E 1465 and review or input by US EPA and other professionals
- Participant in RRNC 2.0 standard development

Richmond American Homes Radon Program Elements

- Active radon control system installed by existing subcontractor base or local mitigation contractors
- Subcontractors and superintendents briefed on requirements
  - Plans and details prepared for various configurations, online videos and illustrations available, and ongoing guidance during third-party observations
- Active systems observed and tested by third-party inspectors. Inspectors certified for radon measurement.
  - Satisfactory mechanical component observation required for short-term radon test deployment
  - Goal systems functional and pre-occupancy short-term test results less than 4.0 pCi/L
  - Actual short-term average 1.0 pCi/L. More than 98.5% homes below World Health Organization guidance of 2.7 pCi/L.
- Test report provided at closing with short-term test results along with offer of no cost long-term radon test for further verification
  - Approximately 5% of buyers request long-term test kit. Approximately one-half returned.

Richmond American Homes
Why Active Systems?

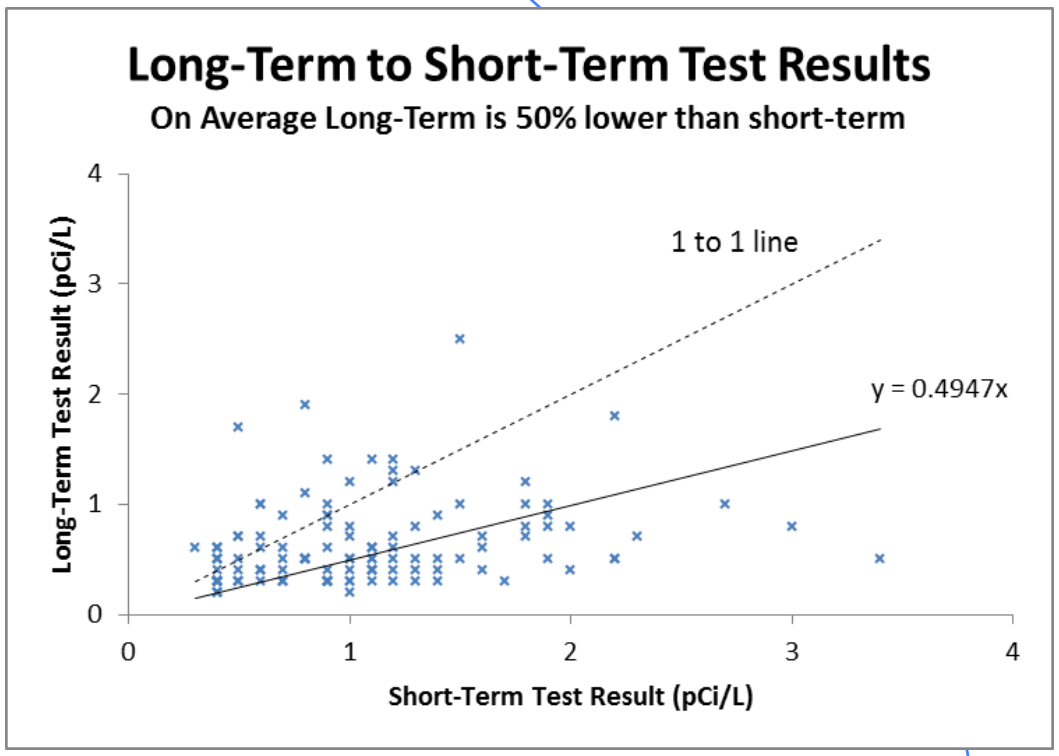
- No known reliable method to assess radon potential in any home before construction
- Expectation active control systems permit best opportunity for consistent long-term reductions. As stated in ASTM E 1465, "Fan powered soil depressurization .... offers the most effective and most reliable radon reduction of all currently available strategies. Historically, far more fan-powered soil depressurization radon reduction systems have been successfully installed and operated than all other radon reduction methods combined."
- Homeowners less confused by active only approach as opposed to multiple step process with passive/test/fix approach when they otherwise may anticipate it to be fully functional when taking possession
- Bottom line: Customer satisfaction and more reliable mitigation

Richmond American Homes Lessons

- An observation by qualified third-party inspectors essential
  - After 5 years and more than 7,500 homes, nominal deviations still periodically found justifying the need for system observations
- Turnover of vendors and employees requires continued awareness and training
  - Independent inspectors aid in this process
- Building Departments are sometimes puzzled with Active only approach
  - Appendix F of the IRC not frequently adopted
  - Additional items installed beyond that in Appendix F where adopted

Richmond American Homes Long-term Post Occupancy to Initial Short-term Pre-Occupancy Test Comparison

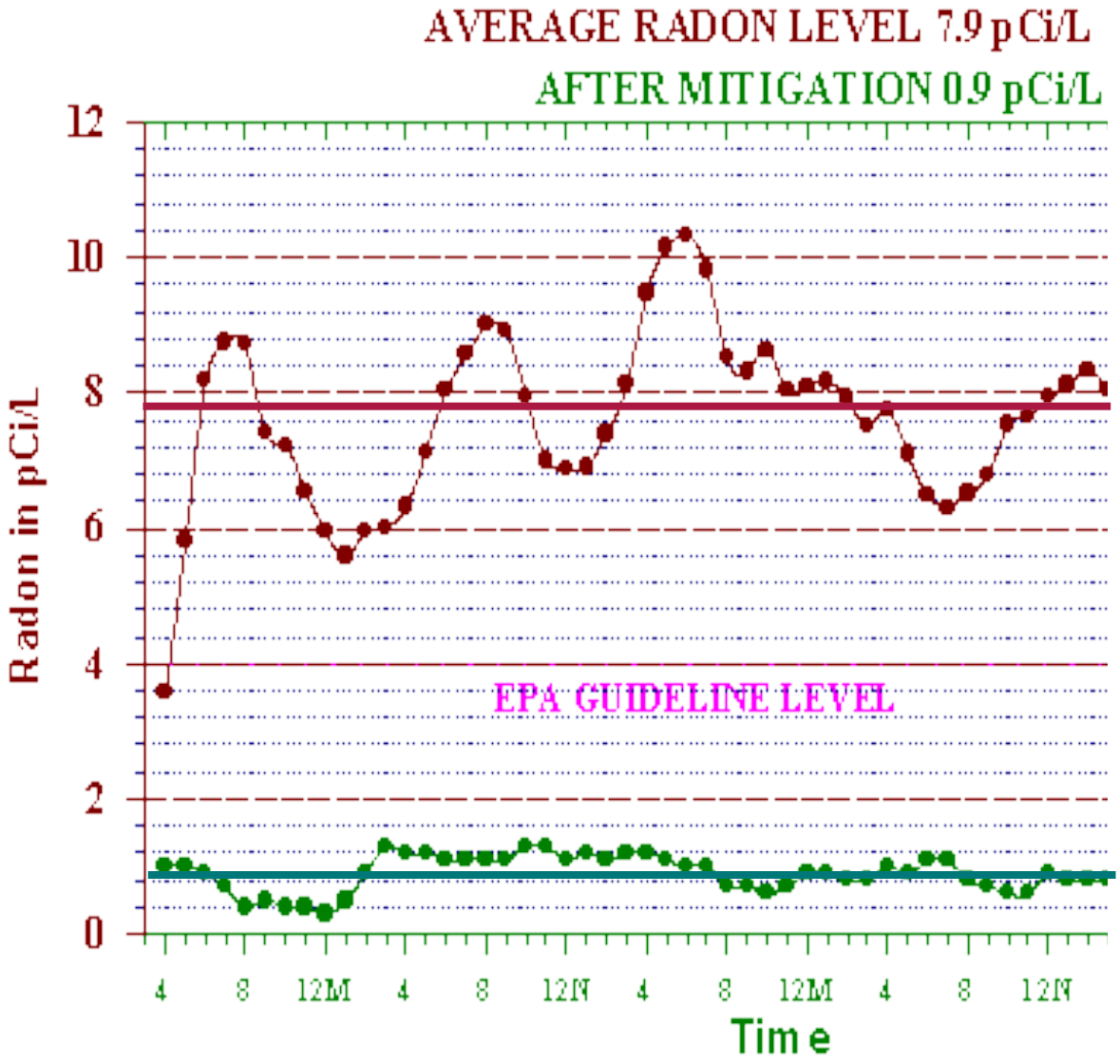
- Long-term test results generally support averages less than short-term test results
- Long-term test results verify short-term pre-closing testing validity



Why Build Using Radon Resistant Techniques

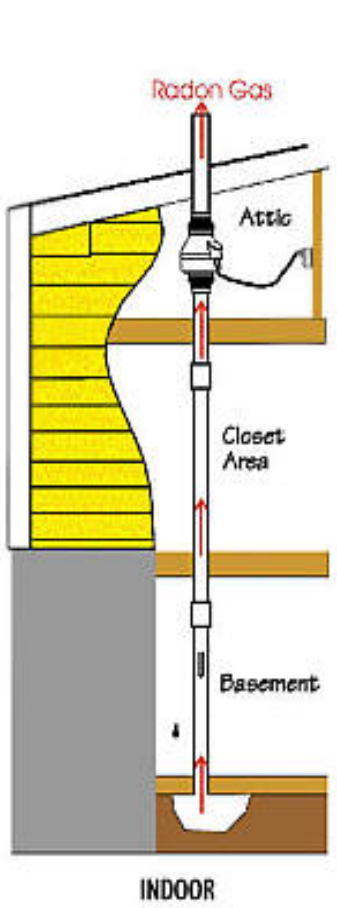
- Radon-resistant new construction (RRNC) typically costs a builder between $250 and $750.
- RRNC could cost less than $250 if the builder already uses some of the same techniques for moisture control.
- Energy and moisture reduction benefits
- To reduce incidence of lung cancer
- To reduce potential liability

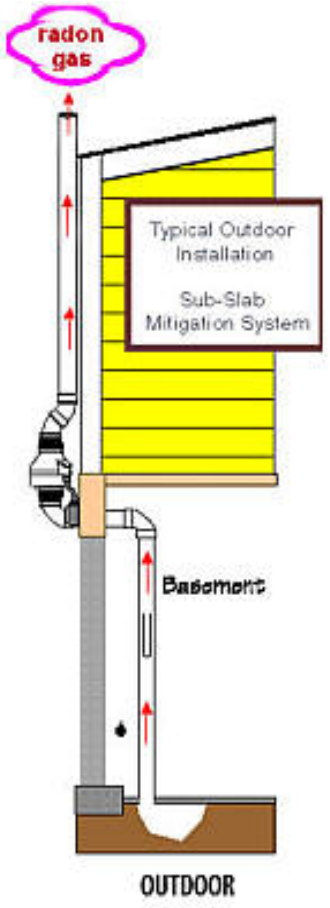
Active Mitigation Is the Best Bet!



Indoor Fan

Outdoor Fan





Questions/Discussion

- **Builders who have been successful?**
- **Mitigators who have worked successfully with builders?**
- **Comments and suggestions?**
- **Thank You!**

Contacts

- **Bruce Snead, Kansas State University, Manhattan, KS bsnead@ksu.edu**
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